Center for Embedded Systems

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Synchronizing Finite State Machine Controllers for Distribution Systems

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Project Overview and Description

- **Project Description**

  Distribution system: Suppliers (or “generators”)
  Consumers (or “loads”)
  Network of Switches.
  generators and switches controlled by FSM

- **Problem**

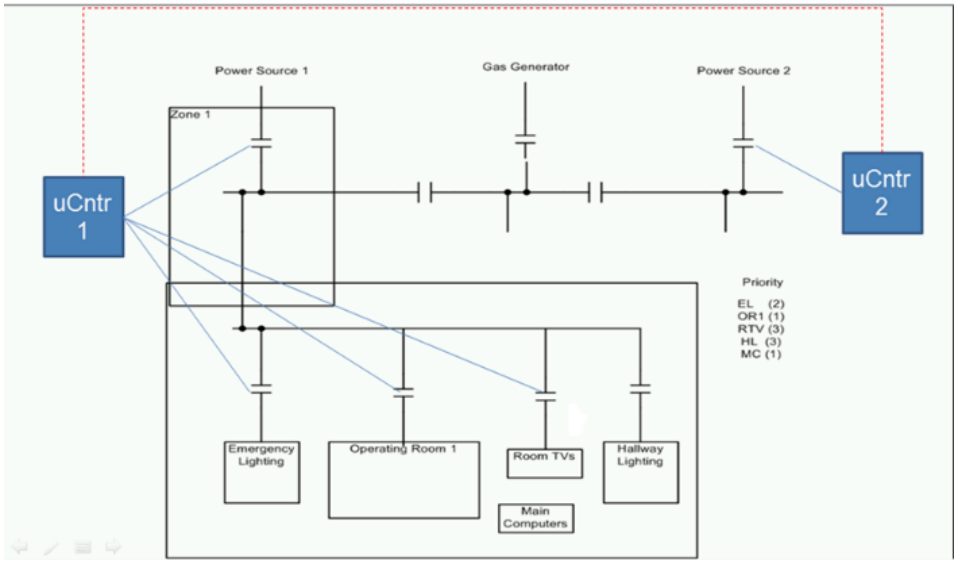
  Response to Failure and/or Reconfiguration Triggering Events

  - Synchronize individual FSMs
  - decentralized/distributed scheme
  - consensus

Approach

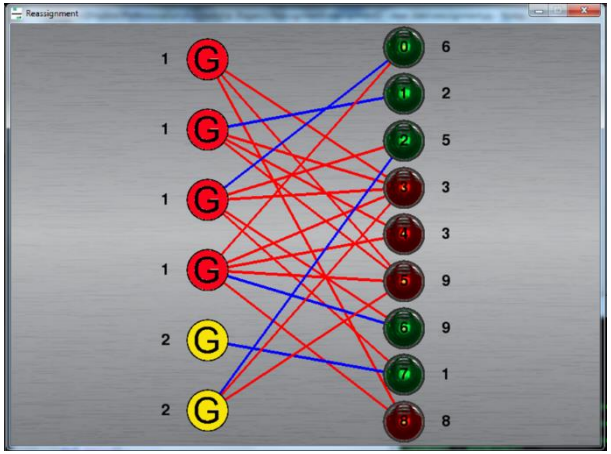
PREVIOUS:

1) Developed in OMNET a decentralized algorithm so that all controllers learn the current topology of the network.
2) Developed Bipartite Matching Formulation to associate Generators to Loads.



PROPOSED:

1) Formulate Integer Linear Program (ILP) to associate Generators to Loads with Conflicts and Priorities.
2) Develop Heuristic and compare with the ideal (ILP)
3) Given a relay distribution network, find all conflicting assignments.
4) Timing considerations for Hand-over after Generator failure.



Novelty

- **Novelty**

  Existing work:

  Fault-tolerance in Distributed Asynchronous Systems
  Mathematical theory on decentralized control
  & coordination of Discrete-Event Systems (DES)

No experimental verification has been given in the literature for specific systems. The proposed work will develop a practical methodology for a real-world industrial problem, namely the control/reconfiguration of the power supply system of an aircraft. The synchronization, consensus, and reconfiguration procedures will be simulated in OPNET.

- **Potential member company benefits**
  - **General model of a distribution system**
    (“suppliers,” “consumers,” “network of switches”) :
  - **General reconfiguration events (“failure,” “load balancing”)**

    it can be useful in many situations.

Project Tasks/ Deliverables

	Description	Date	Status
1	ILP formulation	Q1	Ongoing
2	Development of Heuristic and comparison with the ideal solution in terms of time and quality of solution.	Q2	Not yet started
3	Relay Configuration Algorithm for conflicting paths in relay distribution network	Q3	Not yet started
4	Timing Considerations and Scheduling for Hand-overs during Reconfiguration	Q4	Not yet started

Deliverables:

- **Comprehensive report on the DS modeling and synchronization, consensus, and reconfiguration procedures for the avionics power supply system.**
- **Software prototype tool (OPNET) and algorithms.**

Load Priority Mapping

- Original Priorities (arbitrary values but sorted)
  - P1, P2, P3, P4, P5
  - P1: Highest
  - a_i : # of loads with priority Pi
- Assign new Priorities: Q1, Q2, Q3, Q4, Q5
- P5 => Q5 = 1
- P4 => Q4 = a_5 + 1
- P3 => Q3 = (a_5+1) * (a_4+1)
- P2 => Q2 = (a_5+1) * (a_4+1) * (a_3+1)
- P1 => Q1 = (a_5+1) * (a_4+1) * (a_3+1)* (a_2+1)

Integer Linear Program

Maximize $\sum_{i=1}^{n} L_i * P_i$

subject to :

for each load *i*:

Σ_j **(incoming edge$_j$) <=** L_i

for each source *k* :

Σ_j **(outgoing edge$_j$) <= source_capacity** C_k

for each conflicting pair (edge$_i$, edge$_j$) :

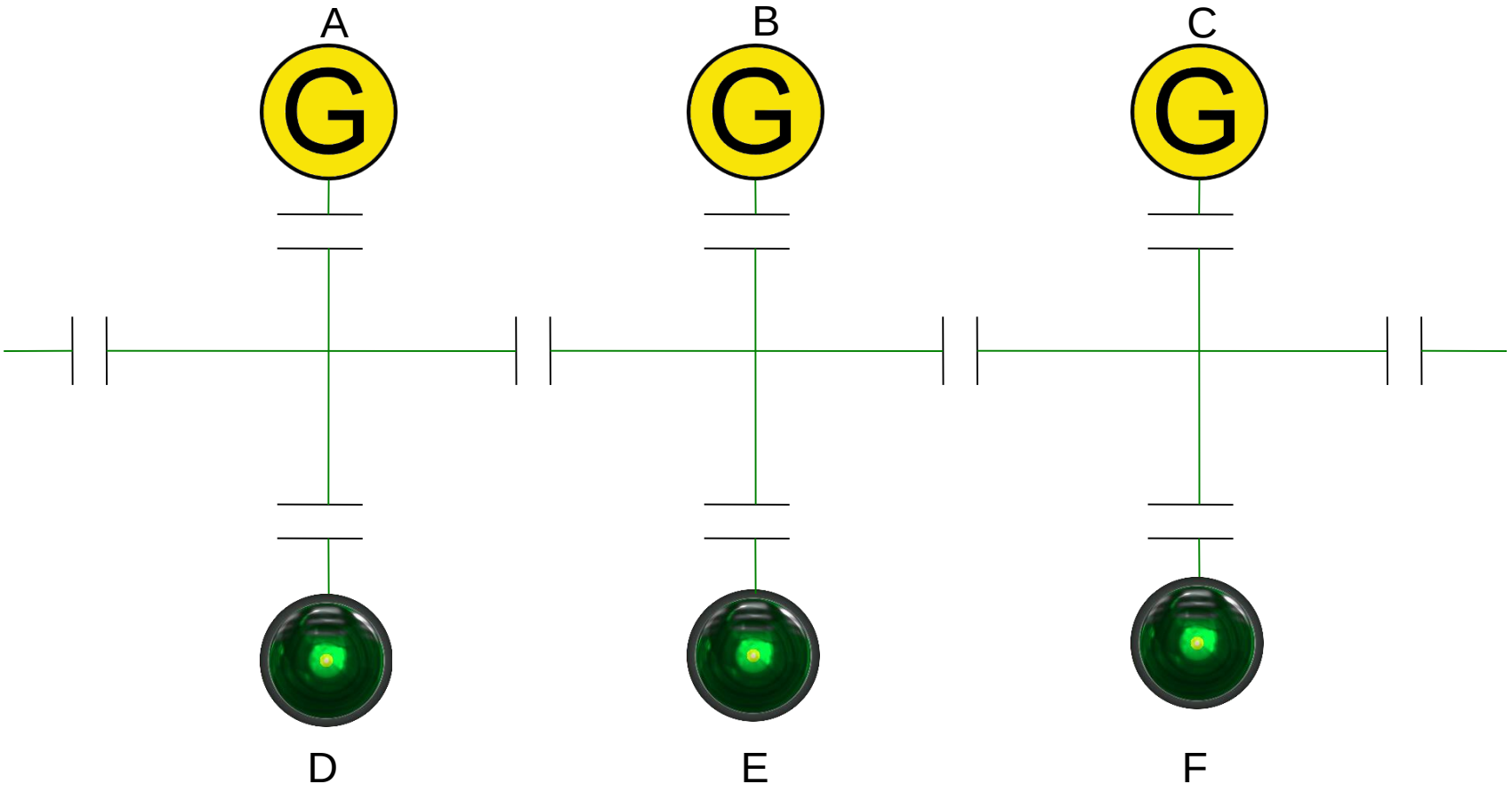
edge$_i$ + edge$_j$ <= 1

Integer Variables:

0 <= edge$_j$ <= 1 (for all edges *j*)

0 <= L_i **<= 1 (for all loads *i*)**

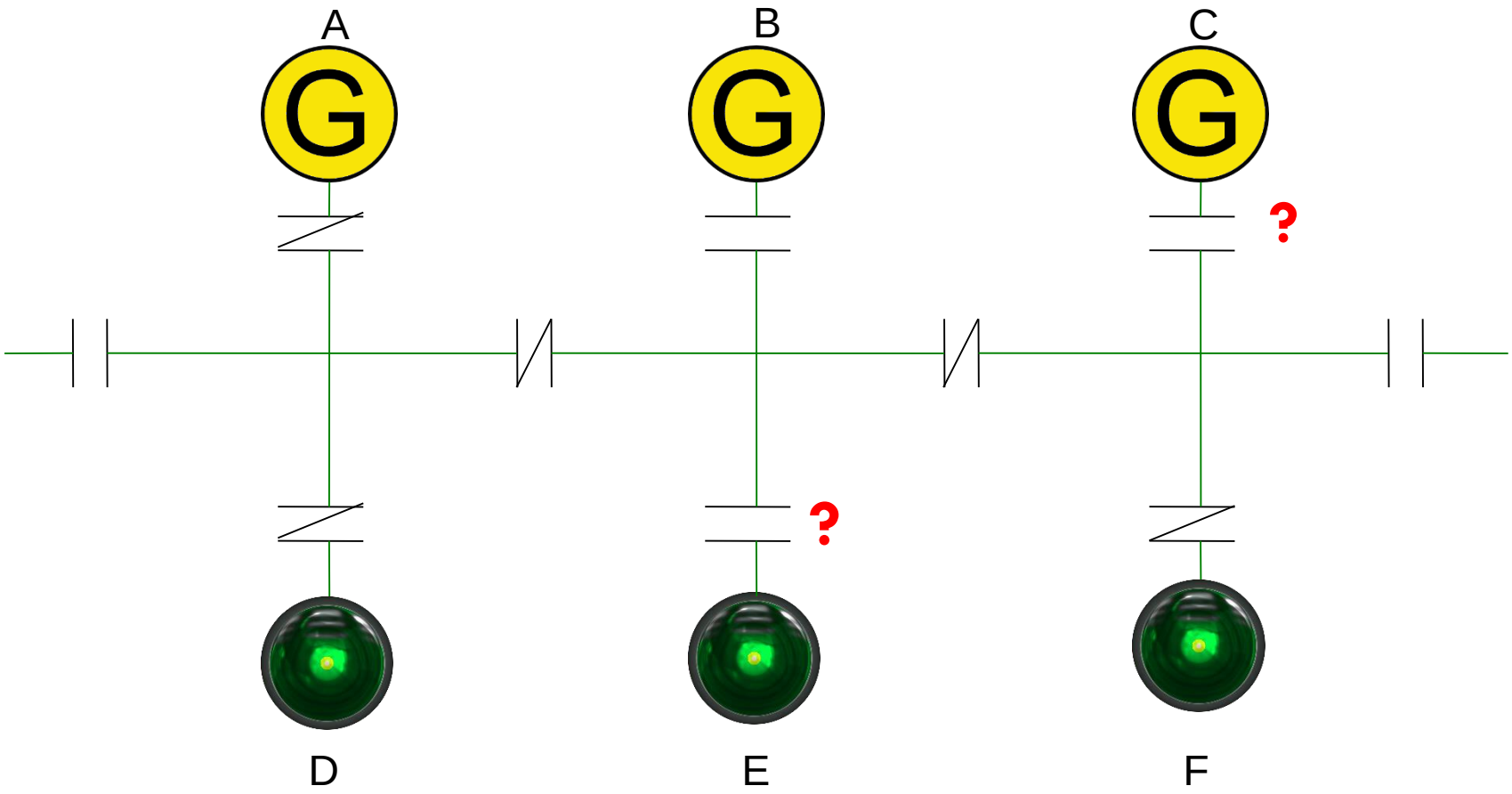
Technical Detail 1 Relay Configuration



Many possible matchings
(A-D, B-E, C-F)
(A-D, A-E, A-F)
(A-D, B-E, B-F)
(A-D, A-F, C-E)

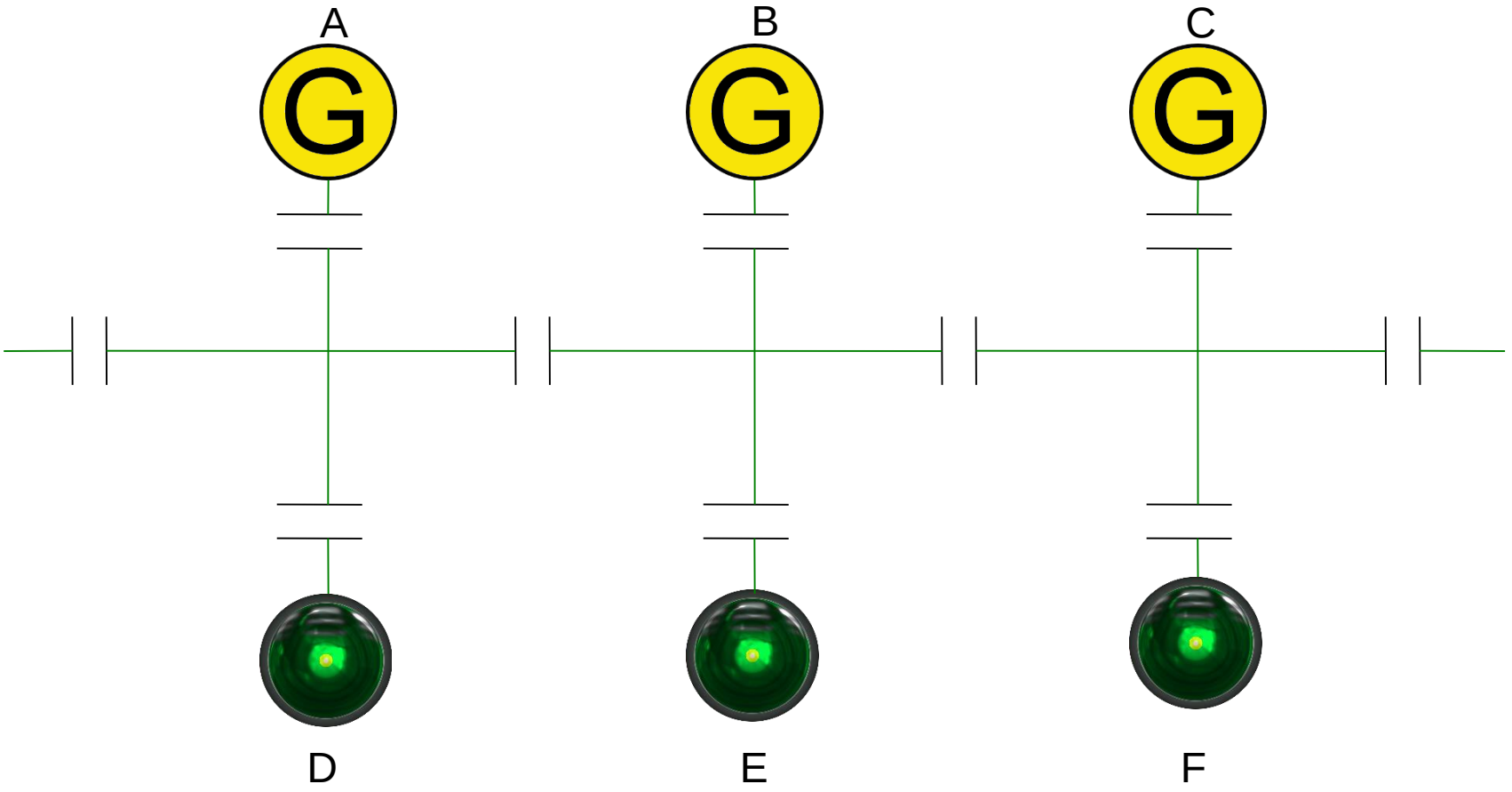
Not all are feasible due to Relay Dependencies

Technical Detail 2 Relay Configuration



Infeasible matchings
(A-D, A-F, C-E) (A-D, A-F, B-E)

Technical Detail Conflicting Pairs



Conflicting Pairs
A-E B-D
A-F B-D
A-F C-E
B-F C-E

Executive Summary

In the proposed approach, we plan to develop algorithms so that

- (i) Strict Priority is enforced: all loads with the highest priority are supported as much as possible, i.e., no load with a higher priority is ever excluded even if many more loads of lower priority could be supported.
- (ii) Consensus on which relays to turn on/off is automatically reached by the matching formulation and the pre-computation of the conflicting pairs.
- (iii) the reconfiguration of the switches is done in the appropriate order so that no transient forbidden states are ever created.

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